UCRL-AR-133352 Rev 1

HVAC Systems in Nonreactor Nuclear Facilities

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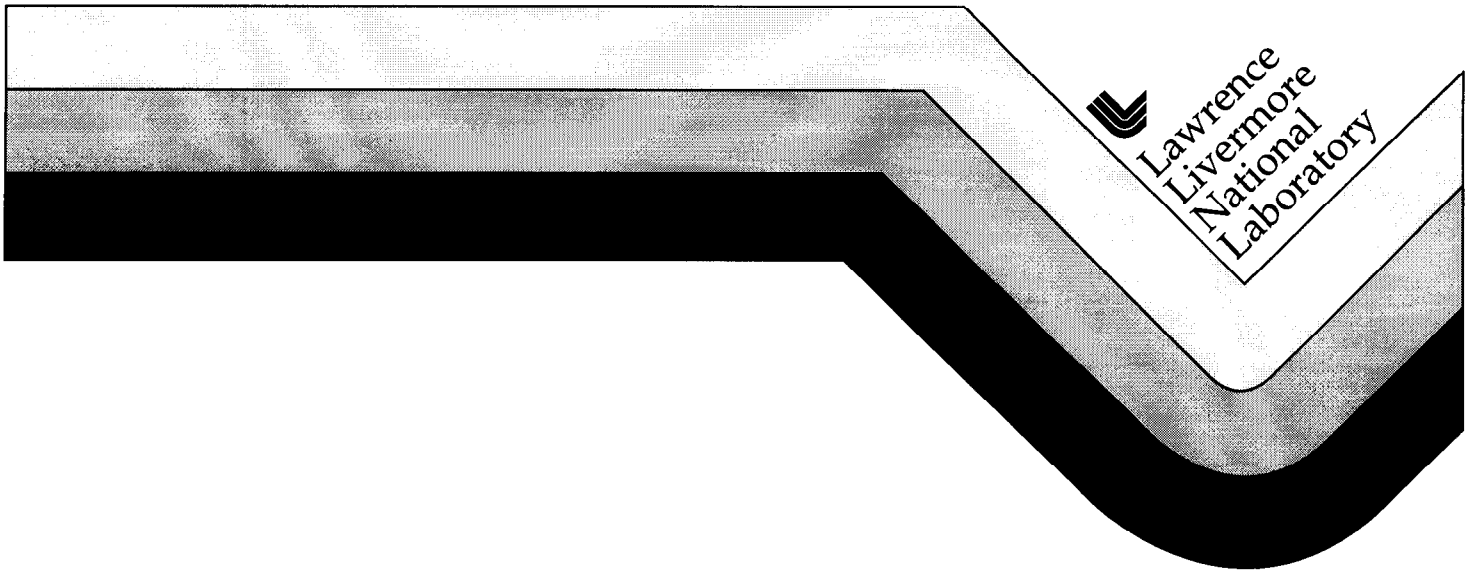
May 1999



Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract W-7405-ENG-48.

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Lawrence Livermore National Laboratory

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Preface

This standard for HVAC Systems in Nonreactor Nuclear Facilities is one of several local Lawrence Livermore National Laboratory (LLNL) environmental, safety, and health standards that was prepared during the Work Smart Standards Closure Process to address areas not adequately covered by Department of Energy orders or national consensus standards. The original version was approved on March 16, 1999. Questions or comments about this standard should be addressed to the Plant Engineering Design and Construction Division Leader.

1.0 General Information

1.1 Purpose

This standard gives design considerations for the design of heating, ventilating, and air conditioning (HVAC) equipment and systems for nuclear facilities at LLNL. These design considerations shall be used for new facilities design.

1.2 References[1]

The following documents form a part of this standard. Unless otherwise indicated, the issue in effect is the latest adopted edition.

- 10 CFR 835, "Occupational Radiation Protection."
- DOE Order 5480.23, "Nuclear Safety Analysis Reports."
- DOE Order 420.1, "Facility Safety."

1.3 The Role of the Safety Analysis Report

The Safety Analysis Report (SAR; written in accordance with DOE Order 5480.23 and DOE O 420.1, as required for all nuclear facilities) shall establish the minimum acceptable performance requirements for the ventilation system and the response requirements of system components, instrumentation, and controls under all operations.

Small incremental projects such as fume hood additions shall have as their design basis the assumptions given in existing SARs that are relevant to the systems that form the context of the proposed project.

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[1] For additional information about HEPA filters, please see *HEPA Filter and In-place Leak Testing Standard* (UCRL-AR-133354).

2.0 Design Considerations

2.1 General Ventilation and Off-Gas Criteria

These criteria cover ventilation and off-gas systems, or portions of them, that are classified as safety class items in accordance with the facility-specific SAR.

A. Safety class ventilation and off-gas systems are generally designed to operate in conjunction with physical barriers to form a confinement system to limit the release of radioactive or other hazardous material to the environment and to prevent or minimize the spread of contamination within the facility.

B. Ventilation and air-conditioning systems designed to provide a comfortable working environment and whose functions are not necessary to provide confinement are generally not designed as safety class systems.

C. Ventilation systems shall be designed to provide a continuous airflow pattern from the environment into the building, and then from noncontaminated areas of the building to potentially contaminated areas, and then to normally contaminated areas. Thus, the airflow is toward areas of higher radioactive or hazardous material contamination. Dampers shall be located so that cross-contamination will not occur in case of a localized release of material.

D. Electrostatic air cleaners shall not be used in systems recirculating air.

E. Ventilation system balancing shall be specified to ensure that the building air pressure is always negative with respect to the outside atmosphere.

F. Portions of ventilation and off-gas systems that provide required functions following a seismic event shall be designed to be functional following a design basis earthquake (DBE).

G. The use of downdraft ventilation within occupied process areas shall be considered as a means to reduce the potential inhalation of contamination for high-density process material.

H. The failure of ventilation and off-gas systems not designated as safety class systems shall not prevent other facility safety class systems from performing their required safety functions.

I. Hydrogen gas storage areas and process areas that use hydrogen shall have provisions for sufficient ventilation to ensure that, under all conditions (i.e., normal operations, anticipated operational occurrences, and design basis accident [DBA] conditions), the hydrogen concentration in the air and/or off-gas will never exceed 1 percent by volume.

J. Gas storage areas and process areas that use hazardous materials shall have ventilation systems designed to ensure that the airborne hazardous material concentrations do not exceed the limits referenced in DOE O 440.1A and are as low as reasonably achievable (ALARA) in the workplace environment. Effective loss-of-ventilation alarms shall be provided in all of these areas.

K. Suitable off-gas stream pretreatment shall be provided upstream of the off-gas clean-up system to remove or reduce the concentration of chemicals that would adversely affect system operation.

L. Components of safety class ventilation and off-gas systems that require electric power to perform their safety functions shall be considered safety class loads.

M. Adequate instrumentation and controls shall be provided to assess ventilation or off-gas system performance and allow the necessary control of system operation.

N. Equipment in ventilation and off-gas systems shall be appropriately qualified to ensure reliable operation during normal operating conditions, anticipated operational occurrences, and during and following a DBE.

2.2 Confinement Ventilation Systems

A. The design of a confinement ventilation system shall ensure the ability to maintain desired airflow characteristics when personnel access doors or hatches are open. When necessary, air locks or enclosed vestibules shall be used to minimize the impact of this on the ventilation system and to prevent the spread of airborne contamination within the facility. The ventilation system design shall provide the required confinement capability under all credible circumstances including a single-point failure in the system.

B. If the maintenance of a controlled continuous confinement airflow is a Technical Safety Requirement (TSR), electrical equipment and components required to provide this airflow shall be supplied with safety-class electric power and provided with an emergency power source.

C. Air clean-up systems shall be provided in confinement ventilation exhaust systems to limit the release of radioactive or other hazardous material to the environment and to minimize the spread of contamination within the facility as determined by the safety analysis. The following general clean-up system requirements shall be met, as appropriate, for ventilation system design:

1. The level of radioactive material in confinement exhaust systems shall be continuously monitored. Alarms shall be provided that will annunciate in the event that activity levels above specified limits are detected in the exhaust stream. Appropriate manual or automatic protective features that prevent an uncontrolled release of radioactive material to the environment or workplace shall be provided.

2. To limit on-site doses and to reduce off-site doses by enhancing atmospheric dispersion, elevated confinement exhaust discharge locations are required. The height of the exhaust discharge location shall ensure that the calculated consequences of normal or accidental releases shall not exceed the radiological guidance contained in the applicable SAR. In addition, to the extent practical, all normal and accidental releases shall be maintained at ALARA levels.

3. An elevated stack shall be used for confinement exhaust discharge. Provisions shall be made to ensure an adequate ventilation exhaust discharge path in the event of stack failure. The stack shall be located so that it cannot fall on the facility or an adjacent facility containing safety class items. The alternative is the construction of a stack that shall remain functional following a DBE, severe natural phenomena, and man-made events. Stack location and height shall also consider intakes on the facility and adjacent facilities to preclude uptake. If a TSR has been prepared which covers the stack, the TSR requirements shall be satisfied.

4. Safety class air-filtration units shall be designed to remain functional throughout DBA and to retain collected radioactive material after the accident.

5. Air-sampling locations shall meet American Conference of Governmental Industrial Hygienists/American Society of Heating, Refrigerating, and Air Conditioning Engineers (ACGIH/ASHRAE) criteria. Sample-collecting devices shall be located as close to the sampling probe as possible.

6. The number of air-filtration stages required for any area of a facility shall be determined by safety analysis based on the quantity and type of radioactive materials to be confined.

7. Air-filtration units shall be installed as close as practical to the source of contaminants to minimize the contamination of ventilation system ductwork.

8. Ducts shall be sized for the transport velocities needed to convey, without settling, all particulate contaminants.

9. Air-filtration units shall be located and provided with appropriate radiation shielding to maintain occupational doses ALARA during operations and maintenance.

10. Air-filtration units shall be designed for ease of recovery of fissile material and other materials capable of sustaining a chain reaction in case of an accident as well as during normal operations.

11. The clean-up system shall have installed test and measuring devices and shall facilitate monitoring operations, maintenance, and periodic inspection and testing during equipment operation or shutdown, as appropriate.

12. Where spaces, such as a control room, are to be occupied during abnormal events, safety class filtration systems shall be provided on the air inlets to protect the occupants. As a minimum, air inlets shall be filtered to limit the loading of exhaust filters with normal atmospheric dust.

13. Either high-efficiency particulate air (HEPA) filtration or fail-safe backflow prevention for process area intake ventilation systems shall be provided.

14. Consideration shall be given to providing roughing filters or prefilters upstream of a HEPA filter to maximize the useful life of the HEPA filter and reduce radioactive waste volume.

D. Hot cell exhaust systems shall be meet the following criteria:

1. Exhaust prefilters and HEPA filters shall be installed in such a manner as to facilitate filter changing and repairs.

2. Standby filters provide backup protection and facilitate changing the primary filters without shutting down the exhaust fans. Standby filters shall be installed outside the cell and sealed in an acceptable enclosure for direct maintenance.

3. All exhaust systems shall have monitors that provide an alarm if the concentration of the hazardous material in the exhaust exceeds specified limits.

E. In facilities where plutonium or enriched uranium is processed, the following additional requirements shall be met:

1. Wherever possible, the designer shall provide enclosures for confining the process work on plutonium and enriched uranium. (Design criteria for enclosures of radioactive and other hazardous materials are not provided as part of this standard.) When these confinement enclosures are specified and designed, consideration shall be given to whether room ventilation air can be recirculated. If a recirculation ventilation system is provided, the design shall provide a suitable means for switching from the recirculation mode to a once-through ventilation system.

2. The facility SAR shall establish the minimum acceptable performance requirements for the ventilation system and the response requirements of system components, instrumentation, and controls under normal operations, anticipated operational occurrences, and DBA conditions.

3. The facility SAR shall determine system requirements such as the need for redundant components, emergency power for fans, dampers, special filters, and fail-safe valve/damper positions. The SAR shall determine the type of exhaust filtration required for any area of the facility during normal operations, anticipated operational occurrences, and DBA conditions.

4. If advantageous to operations, maintenance, or emergency personnel, the ventilation system shall have provisions for independent shutdown. Shutdown of a ventilation system under such conditions shall be considered in light of the effects on airflows in other interfacing ventilation systems. When a system is shut down, positive means of controlling backflow of air to noncontaminated spaces shall be provided by positive shut-off dampers, blind flanges, or other devices.

5. Equipment to continuously monitor oxygen levels shall be provided for occupied working areas of facilities equipped with significant quantities of inert or oxygen-deficient process glovebox lines.

6. The supply air to enclosures that confine the processing of plutonium and enriched uranium shall be filtered by HEPA filters at the ventilation inlets to the enclosures and area confinement barriers to prevent the transport of radioactive contamination in the event of a flow reversal.

7. If room air is recirculated, at least one stage of HEPA filtration shall be provided in the recirculation circuit. The design shall include redundant filter banks and fans that shall be located based on the results of the safety analysis. If recirculation systems are used, a means shall be provided to prevent contaminated process enclosure air from exhausting into the working area rooms. Process enclosure air (from hoods, gloveboxes, etc.) shall be treated and exhausted so there is no potential for recirculation to occupied areas.

8. Ventilation system components and controls that require electric power to perform safety functions shall be supplied with a safety class uninterruptible power supply (UPS) and/or emergency power supply as required by a systems design/safety analysis.

9. The designer shall specify and locate components in the exhaust systems to remove radioactive materials and noxious chemicals before the air is discharged to the environment. These components shall be capable of safely handling products of combustion. These systems shall be designed to operate under DBA conditions including the design basis fire (DBF). The exhaust system design shall ensure that effluents are safely directed through the appropriate ventilation ducts and not spread beyond the physical boundary of the ventilation system unit treated.

10. The safety analysis shall specify the number of required exhaust filtration stages to limit the quantity and concentration of airborne radioactive or other hazardous materials released to the environment from any area of the facility. The design shall include all necessary cleaning and detection equipment for detection and removal of noxious chemicals from the exhaust ventilation system.

11. HEPA filters shall be installed at the interface between the enclosures that confine the process and the exhaust ventilation system to minimize the contamination of exhaust ductwork. Prefilters shall be installed ahead of HEPA filters to reduce HEPA filter loading. The filtration system shall be designed to allow reliable in-place testing of the HEPA filter and simplify filter replacement.

12. Separate exhaust ventilation system ductwork and the initial two stages of filtration shall be designed for exhaust air from enclosures that confine the process (e.g., gloveboxes). These systems shall maintain a negative pressure inside the enclosure with respect to the operating area. These systems shall be designed to remove moisture, heat, and explosive and corrosive gases, as well as other contaminants. These systems shall be designed to automatically ensure adequate inflow of air through a breach in the enclosure confinement shown in the SAR to be the result of a credible accident.

13. Enclosures that confine the process and are supplied with gases at positive pressure shall have positive-acting pressure-relief valves that relieve to the exhaust system to prevent overpressurization of the process confinement system.

14. The design of air-cleaning systems for normal operations, anticipated operational occurrences, and DBA conditions shall include the use of the following equipment as directed by the SAR:

    — Prefilters

    — Scrubbers

    — Process vessel vent systems—HEPA filters

    — Sand filters

    — Glass filters

    — Radioiodine absorbers

    — Demisters

    — Condensers

    — Distribution baffles

    — Pressure and flow measurement devices

15. Airborne contaminant cleaning systems shall be designed for convenient maintenance and the ability to decontaminate components and replace components in the supply, exhaust, and clean-up systems without exposure of maintenance or service personnel to hazardous materials. Filtration systems shall be designed so that a bank of filters can be completely isolated from the ventilation systems during filter element replacement.

2.3 Off-gas Systems

A. The sources and characteristics of radioactive material in off-gas systems shall be identified. The design of an off-gas system shall be commensurate with the characteristics of the radioactive material in the off-gas and the risk associated with its release as an effluent.

B. The design of the off-gas system shall ensure that off-site doses resulting from normal system operation are ALARA and maintained within the limits set by the SAR.

C. Portions of off-gas systems and components that are required to control or limit the release of radioactive material to the environment or for safe operation of the system shall be provided with redundancy.

D. Electrical equipment and components of off-gas systems that require electric power to perform their safety functions shall be considered safety class loads.

E. Adequate instrumentation shall be provided to monitor and assess system performance and to provide necessary alarms. Appropriate manual or automatic protective features shall be provided to prevent an uncontrolled release of radioactive material to the environment and to minimize the spread of contamination within the facility.

F. The off-gas system shall be designed to allow periodic maintenance, inspection, and testing of components.

G. The system's capacity shall be consistent with the needs for handling off-gas from components and systems during normal operations, anticipated operational occurrences, and DBA conditions. Process system tanks and other sealed components shall be vented to an off-gas system.

H. The design of process confinement off-gas treatment systems shall preclude the accumulation of potentially flammable quantities of hydrogen generated by radiolysis or chemical reactions within process equipment.

I. Vents from liquid components shall be provided with traps and drains to prevent inadvertent flooding of off-gas systems.

J. Adequate shielding shall be provided for filters, absorbers, scrubbers, and other off-gas treatment system components to maintain occupational exposures within the limits specified in 10 CFR 835. In addition, to the extent practical, the shielding design shall use ALARA principles to minimize overall exposures.

K. Corrosive gases and particles from vats, scrubbers, and similar equipment in gloveboxes shall be neutralized prior to reaching the HEPA off-gas filters.

L. Air-ventilated gloveboxes shall have the ability to safely contain in-box contaminants when an access port is opened or a glove ruptures.

M. Vent streams containing UF_6 shall be equipped with chemical traps to remove radionuclides from the gases before they are vented to the atmosphere. The following are typical vents to be equipped with traps:

— Purge cascade

— Cold recovery

— Buffer seal exhaust stations

— Wet-air evaluation stations

N. Traps shall be designed for nuclear criticality safety under conditions of design loading of fissile or other materials capable of sustaining a chain reaction. The design shall also minimize the spread of contamination during replacement.

O. All vent streams having the potential of containing significant quantities of radioactive material shall be processed by an off-gas clean-up system before being exhausted to the environment. The clean-up systems shall be designed to remove particulates and noxious chemicals and control the release of gaseous radionuclides.